

# PATENT SPECIFICATION

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(19)



## (54) GAS-FIRED, WARM-AIR HEATING SYSTEMS

(71) We, JOHNSON & STARLEY LIMITED, a British Company, of Rothersthorpe Crescent, Northampton, NN4 9JF, do hereby declare the invention for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:-

This invention relates to gas-fired, warm-air heating systems in which air is heated by passing it over a heat-exchanger and then passed along a duct or ducts to a space or spaces to be heated.

According to the invention there is provided a gas-fired, warm-air heating system comprising a gas flow control valve for controlling the amount of gas supplied to a burner according to the ambient temperature of a space to be heated, a heat-exchanger arranged to be heated by the gas burner, a fan for directing air to be heated over the heat-exchanger and for assisting the flow of warm air through a duct or ducts of the system, and means for continuously controlling the speed of the fan motor in accordance with the temperature at a position at or near to the heat-exchanger, thereby to maintain the temperature of the air entering the space, or spaces, substantially constant.

The gas-flow control valve may be a valve having three states, a first state in which the flow of gas to the burner is at a first, maximum rate when the ambient temperature is less than a first predetermined value, a second state in which the flow of gas is cut-off when the ambient temperature is greater than the second, higher predetermined value and a third state in which the flow of gas is at a second, intermediate rate when the ambient temperature is equal to or between the said first and second predetermined values.

The gas-flow control valve may be a continuously-modulating type of valve by

which the flow of gas is controlled according to the ambient temperature, the valve being arranged to supply gas to the burner at a maximum rate when the ambient temperature is less than a first predetermined value, and to reduce the rate of flow as the ambient temperature increases from the first predetermined value towards a second predetermined value and to cut-off the flow of gas when the said ambient temperature is greater than the said second predetermined value of temperature.

The gas control valve may be controlled by a thermostat or like device which may be positioned in suitable position in a space to be heated.

The means for controlling the speed of the fan may be an apparatus as described or claimed in the Complete Specification of our co-pending application No. 20200/75. Serial No. 1552625.

The invention will now be described by way of example with reference to the accompanying drawings, in which:

Figure 1 shows a block schematic diagram of an embodiment of a domestic, warm-air, gas-fired central heating system according to the invention,

Figure 2 shows a block schematic diagram of another embodiment of a domestic, warm-air gas-fired central heating system according to the invention,

Figure 3 is a simplified block circuit diagram of an embodiment of apparatus for controlling the speed of rotation of the fan motor in the system of Figure 1 or 2,

Figure 4a and 4b show a circuit diagram of another embodiment of apparatus for controlling the speed of rotation of the fan motor, and

Figure 5 is a circuit diagram of another embodiment of apparatus for controlling the speed of rotation of the fan motor.

Referring to Figure 1, there is shown a gas-fired, warm-air central heating system

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comprising a gas control valve 6 for controlling the rate of flow of gas from a supply 7 to a gas burner 8 arranged to heat a heat exchanger 53 mounted in an appliance or a duct 15. The heat exchanger 53 can be provided, if required, with fins (not shown) to increase the strength of its casing and/or to increase the area of the heat-exchange surface. The heat exchanger 53 is provided in the usual way with a combustion air inlet 8a and an outlet 8b whereby exhaust gases can be vented to atmosphere outside the building in which it is located; the combustion air for the burner being kept separate from the circulating air being used to heat the room or rooms. The valve 6 has three states, namely a first state in which it is fully open to allow gas to flow at a first, maximum rate to the burner 8, a second state in which it is closed to cut-off the flow of gas and a third state in which it is partially closed to allow gas to flow at a second, intermediate rate to the burner. Operation of the valve 6 is controlled by a thermostat 9 mounted in a convenient position in a room (not shown) to be heated. Thus when the ambient temperature in the room, as detected by the thermostat 9, is less than a first predetermined value the valve 6, controlled by thermostat 9, is in the first state so that the burner 8 heats the heat exchanger 53 at a maximum rate, when the ambient temperature is greater than a second predetermined value, higher than the first predetermined value, the valve is cut-off and the heat exchanger starts to cool and when the ambient temperature is equal to or between the said two predetermined values the valve 6 supplies gas to the burner at the lower, second rate. Thus there is a three-way control of the heat supplied by the burner 8, rather than the simple ON/OFF control used in conventional systems. The thermostat 9 can, in the usual way, be manually-adjustable by a user of the room to be heated.

Air is forced along the duct 15 in the direction of arrow A by means of a fan 13 driven by a motor 12, the air being heated as it passes over the heat exchanger 53 before being discharged into the room or rooms to be heated.

Referring to Figure 2 there is shown a gas-fired, warm-air central heating system 5' comprising a gas control valve 6' for controlling the rate of flow of gas from a supply 7' to a gas burner 8' arranged to heat the water supply to a heat exchanger 53' mounted in a duct 15', the heat exchanger 53' being provided with a hot water inlet 53a' and an outlet 53b'. The valve 6' has three states, namely a first state in which it is fully open to allow gas to flow at a first, maximum rate to the burner 8', a second state in which it is closed to cut-off the flow

of gas and a third state in which it is partially closed to allow gas to flow at a second, intermediate rate to the burner. Operation of the valve 6' is controlled by a thermostat 9' mounted in a convenient position in a room (not shown) to be heated. Thus when the ambient temperature in the room, as detected by the thermostat 9', is less than a first predetermined value the valve 6', controlled by thermostat 9', is in the first state so that the burner 8' heats the water to the heat exchanger 53' at a maximum rate, when the ambient temperature is greater than a second predetermined value, higher than the first predetermined value, the valve is cut-off and the water starts to cool and when the ambient temperature is equal to or between the said two predetermined values the valve 6' supplies gas to the burner at the lower, second rate. Thus there is a three-way control of the heat supplied by the burner 8', rather than the simple ON/OFF control used in conventional systems. The thermostat 9', can, in the usual way, be manually-adjustable by a user of the room to be heated.

Air is forced along the duct 15' in the direction of arrow A by means of a fan 13' driven by a motor 12', the air being heated as it passes over the heat exchanger 53' before being discharged into the room or rooms to be heated.

The speed of the fan motor 12 in Figure 1 or Figure 2 is controlled by a control apparatus 10 which, in turn, is controlled by the output of a temperature-sensing device in the form of a thermistor 52 suitably positioned close to the heat exchanger 53. The apparatus 10 is arranged to control the speed of the fan 13 such that the rate of flow of air along the duct 15 and into the room increases with increase in temperature detected by thermistor 52.

Thus, in addition to the three way control of the temperature by means of the gas control valve 6, the rate of flow of the heated air is controlled continuously to vary the amount of heat supplied to the room or rooms to be heated. It has been found that this form of control of the air flow rate adds greatly to the comfort of the occupants of the room. This is in distinction to that found with control apparatus provided in conventional systems in which the delivered air fluctuates in temperature due to intermittent burner and fan operation and its flow is periodically interrupted. This intermittent operation can give rise to discomfort in heated rooms because of intermittent fan noise, temperature swings and intermittent air currents, for example if the fan has been off for some time the air in the duct between the heat exchanger and the outlet will be relatively cool and will be discharged into the room ahead of the heated air.

Referring now to Figure 3, there is shown a block diagram of an embodiment of the apparatus 10 for controlling the speed of rotation of the shaded-pole motor 12 in dependence upon the magnitude of an input signal applied to an input terminal 14. The apparatus 10 comprises an analogue to digital (A to D) converter shown within a broken line 16, and having an input 18. The input terminal 14 is coupled through an amplifier 20 to the input 18.

The A to D converter 16 is arranged to convert an analogue signal applied to input 18 into a digital number representative of its magnitude.

The output of the A to D converter 16, in the form of a digital count, is coupled to a motor control means shown within a broken line 22 arranged periodically to decode the digital number and to control the speed of rotation of the motor 12 in dependence upon the magnitude thereof. Thus the speed of rotation of the motor 12 is dependent upon the magnitude of the analogue input signal.

A sample and reset timer 24 is arranged to generate at outputs 26a and 26b a sample and reset pulse 100  $\mu$ s long every 10 secs. The reset pulse is used periodically to reset the A to D converter 16 to a datum level to start a fresh conversion of the input signal and, indirectly, to cause the motor control means to decode the output of the A to D converter 16 each time it has effected a conversion.

The A to D converter 16 comprises a staircase generator 28, typically a resistor and capacitor (not shown) coupled in series between signal ground and a source of alternating current, so that, in operation the potential across the capacitor increases in a stepwise fashion. The staircase generator 28 has a reset input 28a coupled to the output 26a of the sample and reset timer 24 and an output 28b coupled to one input 30a of a comparator circuit 30. Thus the generator 28 supplies to the comparator 30 a staircase waveform which is reset periodically to a datum level. The other input 30b of the comparator 30 is coupled to the input 18. The comparator 30 is a bistable device having an output set to one level when the magnitude of the signal at input 30b is greater than both a first predetermined value and the magnitude of the staircase waveform at input 30a and is reset to its other level when the magnitude of the staircase waveform is equal to or greater than the signal at input 18. The output 30c of comparator 30 is coupled to the control input 32a of a pulse generator 32 arranged to provide pulses to the input 34a of a 4-stage binary counter 34 when the comparator output is set to its said one level. Each stage of the counter 34 has a corresponding

output 34c to 34f coupled to the motor control circuit 22. The outputs 34c to 34f of counter 34 correspond in known manner to counts of 1, 2, 4 and 8 respectively, that is the counter can count input pulses up to a maximum of 16 (that is, 0 and 1 to 15) and the dynamic range of the input signal is such that a full-house count of 15 in counter 34 would result when the input signal reaches or exceeds a third predetermined value which is greater than the first and second predetermined values.

The staircase generator 28 and counter 34 are reset to datum once every ten seconds by a reset pulse applied to inputs 28a and 34b respectively.

The motor control circuit 22 comprises four identical latching circuits 36c to 36f coupled to counter outputs 34c to 34f respectively. The latching circuits 34c to 34f are arranged to control four normally-open switches 38c to 38f respectively which are connected in parallel with four corresponding resistors 40c to 40f connected in series between one terminal 12a of the motor 12 and the neutral terminal 42 of an alternating current supply for the motor 12. Thus closure of a switch will have the effect of shorting its associated resistor. The values of the resistors 40c to 40f are binary weighted so that if the resistance of resistor 38c is R then the resistance of resistors 38d, 38e and 38f is respectively 2R, 4R and 8R. Thus the value of resistance in circuit is indirectly proportional to the count in the counter 34.

The other terminal 12b of the motor 12 is coupled through a normally-open switch 44 to the line terminal 46 of the alternating supply for the motor. Operation of the switch 44 is controlled by the output of the amplifier 20 such that when the magnitude of the output of the amplifier 20 is greater than a second predetermined value (which is typically less than the first predetermined value required to set the comparator 30) the switch 44 is closed so that an energising current flows in the motor 12. The magnitude of the current is determined, externally of the motor 12, by the sum of the resistors 40c to 40f in circuit.

In operation, the sample and reset timer 24 resets the output of the staircase generator 28 to its datum level and counter 34 to zero once every 10 seconds, and the motor control means 22 is arranged to control the speed of the motor 12 during any 10 second period according to the count in the counter 34 at the end of the immediately preceding 10 second period.

When the magnitude of an input potential applied to terminal 14 is such that the output of the amplifier 20 is less than the said second predetermined value the motor is not energised. As the magnitude of the input signal is increased until the output of

the amplifier 20 is equal to the second predetermined value the switch 44 is closed and the motor 12 is energised with all four resistors 40 in circuit so that it rotates at its lowest speed. If the magnitude of the input signal remains at a value between the second and the first, higher predetermined value the apparatus would continue to operate in this manner. When the input is increased still further until the output of amplifier 20 is equal to or greater than the first predetermined value and that of the staircase waveform the comparator 30 is set, to cause the pulse generator 32 to feed pulses to the counter 34. Assuming that the staircase generator 28 and counter 34 have just been reset, the counter will continue to count pulses until the magnitude of the staircase waveform becomes equal to or greater than the output of the amplifier 20 when the comparator 20 will be reset and thus inhibit the pulse generator. Thus it will be seen that the time interval during which the comparator 30 is set and therefore the number of pulses counted by the counter 34 will be dependent upon the magnitude of the input signal.

At the end of the analogue to digital conversion period the motor control means 22 decodes the count in the counter 34. This is achieved by coupling the reset signal from the output of the comparator 30 to an input of each of the latch circuits 36c to 36f in such a way that if an output stage of the counter 34 has changed state since the immediately preceding conversion the corresponding latching circuit is charged accordingly to open or close its associated switch 38. For example, if the count is six, the counter outputs 34c and f would be at zero and 34d and f would be open and 38d and e closed to short out resistors 40d and e and the current through the motor would be increased accordingly to increase the speed of the motor. Thus the speed of the motor is dependent upon the magnitude of the input signal.

At the next reset pulse the counter is reset to zero count, and staircase generator is reset to datum level. If the magnitude of the signal at the input 30b of the comparator 30 is still equal to or greater than the first predetermined value of the comparator 30 is again set to cause pulses to be coupled until the magnitude of the staircase waveform again equals or exceeds that at the input 30b to reset the comparator 30. When the comparator 30 resets, its output also causes the latching circuits 36 to decrease the output of the counter to determine the speed of the motor 12 during the next succeeding conversion period and so on.

Thus there is a sixteen-step control of the current through the motor.

Referring now to Figures 4a and 4b there

is shown a circuit diagram of apparatus 50 according to the invention for controlling the speed of rotation of a motor 12 arranged to drive a fan in a warm-air central heating system according to the resistance of a thermistor 52 situated in the air stream of the fan and close enough to the heat exchanger (not shown) to be responsive to heat radiated or convected therefrom.

The circuit is somewhat similar to that shown as a block diagram in Figure 3 and parts of the circuit which generally correspond to a block in Figure 3 are shown in outline by a broken line bearing the same reference although it will be appreciated that individual components may form part of more than one block.

The thermistor 52, which has a resistance characteristic which decreases with increase in temperature, is connected between input terminals 54a and 54b. Terminal 54a is coupled through a resistor 56 to the base of a NPN transistor 58. A chain of resistors 60, 62, 64 and 66 in series is connected between a +5 volt rail 68 and a zero volt rail 70 and the terminal 54b is connected to the junction of resistor 62 with resistor 64. The transistor 58 has its collector coupled through a relay coil 72 to a +30 volt rail 74, and its emitter connected to the zero volt rail 70. The relay coil 72 has a pair of normally-open contacts 72a connected between one input of the motor 12 and the line terminal 126 of an alternating current supply. A capacitor 76 is connected between the emitter and base of the transistor 58 and a variable resistor 77 is connected between the zero volt rail 70 and the junction of the capacitor 76 with the resistor 56. Three diodes 78a, 78b and 78c poled as shown are connected in series between the emitter of transistor 58 and the junction of resistor 60 with resistor 62 and operate as a voltage regulator with a negative temperature coefficient of resistance to compensate for changes in ambient temperature. Thus the transistor 58 and its associated components can be likened to the amplifier 20 of Figure 3.

A sample and reset circuit shown within a broken line 24 is an astable multivibrator arranged to generate a pulse about 100  $\mu$  secs. long every 10 seconds. The multivibrator 24 comprises two NPN transistors 80 and 81, resistors 82 to 87, capacitors 88 and 89 and a diode 90 connected as shown. Pulses of 100  $\mu$  secs. duration and of opposite polarity appear at the collectors of the two transistors 80 and 81. The resistor 87 has one end coupled to the base of transistor 80 and through resistor 85 to the +5 volt line, and the other end to a 24 volt a.c. rail 92 thereby to synchronise the operation of the multivibrator 24 to a predetermined point on the waveform of the line frequency.

A staircase generator shown within a

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broken line 28 comprises a resistor 94 and a capacitor 96 connected in series between the 24 volt a.c. rail 92 and the zero volt rail 70. The junction of the resistor 94 and capacitor 96 is coupled to the collector of transistor 81 by way of diode 98 so that the capacitor is discharged to a datum level (zero volts) once every 10 seconds by a reset pulse. The end of the resistor 94 remote from the capacitor is connected to the 24 volt a.c. rail 92 so that the capacitor is charged in stepwise fashion by the positive half cycles of alternating current to generate a staircase output waveform.

The output of the staircase generator 28 is coupled by way of a resistor 100 to the input of a bistable circuit shown within a broken line 30. The bistable circuit 30 comprises two NPN transistors 101, 102 the resistor 66, resistors 103, 104 and 105 and a capacitor 106, the input of the circuit 30 being the base of transistor 101.

The bias voltage at the junction of resistors 62 and 64 is dependent upon the resistance of thermistor 52 and hence temperature of the air stream near the heat exchanger. When the resistance of the thermistor 52 is high, that is the temperature is low, the bias voltage is such that the transistor 101 is ON, that is conducting and transistor 102 is OFF, that is substantially non-conducting. When the thermistor resistance falls to a first predetermined value or lower, the bias voltage increases in a negative direction and, assuming the capacitor 96 is discharged or nearly so, the transistor 101 is turned OFF and transistor 102 is turned ON so that the bistable is set to one state. Then, as the magnitude of the staircase waveform increases it will eventually reach a value at which it offsets the change in the bias at the base of transistor 101 due to the change in resistance of thermistor 52 so as to turn ON transistor 101 and turn OFF transistor 102 to reset the bistable circuit 30. Thus the bistable 30 will be set for a time dependent upon the magnitude of the change in the bias level due to change in the resistance of the thermistor 52. The bistable circuit 30 can therefore be likened to the comparator 30 of Figure 3.

A chain of resistors 108, 109 and 110 is coupled between the collector of transistor 102 and the 24 volt a.c. rail 92, a capacitor 111 being connected in parallel with resistor 110. A NPN transistor 112 has its base connected to the junction of resistor 108 with resistor 109, its emitter connected to the zero volt rail 70 and its collector coupled through a resistor 113 to the +5 volt rail 68. Thus part of the circuit is so arranged that when transistor 102 is OFF the bias voltage at the base of transistor 112 is sufficient to ensure that transistor 112 is conducting continuously, that is, it is ON. When transis-

tor 102 is switched ON the bias at the base of transistor 112 is removed and the positive half cycles of alternating voltage from line 92 are sufficient to switch transistor 112 ON and OFF at line frequency. Thus transistor 112 and its associated circuitry within a broken line 32 can be regarded as a pulse generator operative when the bistable circuit 30 is set.

The output of the pulse generator 32, the collector of transistor 112, is connected to the clock input 34a of an integrated circuit, four stage, divide by 16 binary counter 34. The collector of transistor 112 is also coupled to the base of transistor 58 by a resistor 116 for a purpose to be described hereinafter.

The counter 34 also has a reset input 34b coupled to the collector of transistor 80 in the reset timer 24, whereby the counter is reset to zero every 10 seconds.

The outputs of the four stages 34c to 34f corresponding to the first stage of the counter 34 are connected to four identical latching circuits 118 C to F of which only one circuit 118 C is shown in detail.

Each of the latching circuits 118 comprises a NPN transistor 119 having its collector coupled through a resistor 120 to the output of its corresponding counter stage, and its emitter coupled through a capacitor 121 to the zero volt line 70 and through a resistor 122 to the base of a power NPN transistor 123. The emitter of transistor 123 is connected to the zero volt rail 70 and the collector is coupled through a relay coil 124 to the +30 volt rail 74. The base of each transistor 119 is coupled through a resistor 125 to the collector of transistor 102, and the circuit is so arranged that the transistors 119 are maintained non-conducting when transistor 102 is ON and pulses are being counted by the counter 34. When the bistable circuit 30 is reset so that transistor 102 is switched OFF, the bias levels at the bases of the transistors 119 is such that the transistors 119 can conduct to decode the output 0 or 1 of their corresponding counter stages and energise or de-energise relay 124 depending upon the count in the stage. If the count in the counter stage is 0 the relay is not energised and if the count is 1 the relay is energised and this state is maintained until after the bistable circuit 30 has been set and reset once more, that is until the next succeeding conversion of the analogue input signal to a digital representative in the counter.

One side of the motor 12 is coupled through a normally-open relay contact 72a, actuated by relay 72, to the line terminal 126 of the alternating current mains supply and the other side is coupled through four binary weighted resistors 40C to 40F to the neutral terminal 128. The resistors 40C, 40D, 40E

and 40F have resistance values of R, 2R, 4R and 8R respectively. Connected in parallel with each of the resistors 40C to 40F is an associated normally-open relay contact 124C/1 to 124F/1 respectively, each relay contact being actuated by its corresponding relay coil 124.

The power supply for the circuit 50 is shown within a broken line 130.

In operation, when the central heating system is switched-on the heat exchanger will be cold and the resistance of the thermistor 52 high. The fan motor should not be operative as cold air will be circulated to the spaces to be heated.

The staircase generator 28 will operate continuously, generating a staircase waveform which is reset to zero once every 10 seconds by a reset pulse from the sample and reset timer 24. The bistable circuit 20 will be reset with transistor 101 ON and transistor 102 OFF so that the generation of pulses to the counter 34 is inhibited, and the count is zero.

When the thermistor 52 is cool, its resistance will be high and the potential at the junction of resistors 62 and 64 will be high so that sufficient current will flow through resistor 64 to the base of transistor 101 to ensure that transistor 101 is maintained ON even when the capacitor 96 is discharged to substantially zero volts by timer 24.

As the temperature at the thermistor increases, its resistance falls until the bias level at the base of transistor 58 is sufficient to turn it ON, and the resulting collector current energises relay 72 to close the normally-open contacts 72a in the power supply to the fan motor 12. As the contacts 124 are open all of the resistors 40 will be in circuit and the fan motor will rotate at its slowest speed to provide some air flow. This occurs when the temperature at the thermistor is about 50°C.

As the temperature at the thermistor 52 increases the bias voltage at the junction of resistors 62 and 64 reduces. When the temperature at the thermistor is at a value above 55°C, the bias is reduced to a level such that when the capacitor 96 is next discharged by a reset pulse, the transistor 101 is turned OFF and transistor 102 is consequently turned ON, that is the bistable circuit 30 is SET. The resistor 104 and capacitor 106 are "speed-up" components selected to ensure a rapid transition between operative states of the circuit 30.

The bistable circuit 30 remains in the set state until the potential across the capacitor 96 has been increased in stepwise fashion by positive half cycles of alternating current on rail 92 to a value at which it is sufficient to offset the change in bias at the base of transistor 101 due to the change of resistance of the thermistor 52. At this time the

transistor 101 is switched ON again and transistor 102 is switched OFF, to reset the circuit 30. Thus the circuit 30 will be set for a period dependent upon the magnitude of the change in resistance of the thermistor. If the thermistor is heated to a value at which its change in resistance is just sufficient to switch OFF transistor 101, then the circuit 30 will be set for only a short time. If the thermistor 52 is heated to a much higher value then the circuit 30 will be set for a correspondingly longer time. Thus the combination of circuits 20, 24, 28 and 30 can be regarded as analogue input-to-time duration converter.

For the duration of the time that the circuit 30 is set, transistor 102 is ON and the resulting reduction in potential at its collector is such that positive half cycles of alternating voltage on rail 92 can turn transistor 112 ON and OFF at the frequency of the a.c. mains supply. The circuit 32 including transistor 112 is arranged to shape the waveform appearing at the collector to a substantially square wave which is then coupled to the clock input 34b of the counter 34. The values of resistors 109 and 110 are selected to present a suitable value of alternating current to transistor 112 and the capacitor 111 is provided as a "speed-up" component to increase the rate of rise of the waveform.

The resistor 116 is provided to ensure that if a clock pulse is applied to counter 34 prior to switch 72a being closed, then amplifier 20 receives a small pulse to energise relay coil 72 and therefore close switch 72a.

At the end of a conversion period when the transistor 102 is turned OFF, the count in the counter 34 will be dependent upon the length of time the circuit 30 was set and hence on the magnitude of the temperature at the thermistor 52. Being a 4-stage converter the number of pulses counted during a conversion period can have any one of sixteen values, zero to fifteen.

The outputs 34c, 34d, 34e and 34f of the counter 34, corresponding to counts of 1, 2, 4 and 8 respectively are decoded by the latching circuits 118C to 118F which actuate relay contacts 118C/1 to 118F/1 accordingly to adjust the power supplied to the motor 12.

Each base resistor 125 of the latch circuits 118 is connected to the collector of transistor 102 so that when transistor 102 is ON to cause clock pulses to be counted, the transistors 119 are cut-off. At the end of a conversion, transistor 102 is turned OFF and allows the transistors 119 to sample their corresponding counter output stages. If a counter stage has changed its state in the immediately preceding conversion period its associated latch circuit changes state accordingly to energise or de-energise its relay as

the case may be. The latch circuits 118 are then maintained in that state until they take a fresh count sample at the end of the next succeeding conversion period.

5 By selecting the resistors 40C to 40F to have a binary relationship to each other it is thus possible to convert the binary number in the counter to a decimal value of resistance and thus to vary the voltage to the fan in regular steps according to the count in the counter. The air flow caused by the fan will thus be increased or decreased with increase or decrease in temperature at the thermistor thus tending to stabilise the temperature.

10 Connected in parallel with the resistor 100 is a series circuit comprising a resistor 132 and three diodes 133, 134 and 135 poled as shown which introduce a non-linearity into the control system which tends to compensate the non-linear voltage against speed relationship of the motor.

15 Various modifications can, of course, be made to the circuit without departing from the scope of the invention. For example, the binary-weighted resistors 40 could be replaced by four binary-weighted voltages derived from separate windings of a transformer.

20 As the whole process is directly geared to a specific point on the supply waveform, the switches 124C/1, 124D/1, 124E/1 and 124F/1 will open at, or near to, the zero voltage point on the supply waveform to minimise sparking (interference) and prolong the life of the switches.

25 Referring now to Figure 5 there is shown a circuit diagram of apparatus 210 for controlling the speed of an electric motor 212 in accordance with the value of resistance of a resistor 214. As described with reference to Figure 4 the motor 212 is arranged to drive a fan in a warm-air central heating system and the resistor 214 is a thermistor situated in the air stream and in a position to receive radiant heat from the heat exchanger.

30 The apparatus 210 comprises a PNP transistor 216 having its emitter coupled through a preset resistor 218 to a +24 volts unsmoothed line of a power supply 220 and its collector coupled through a resistor 222 to base 2 of a unijunction transistor 224. A capacitor 226 and resistor 228 are connected in parallel between the base and emitter of transistor 216. The base of the transistor 216 is coupled to the emitter of the unijunction transistor 224 by way of the thermistor 214 and a resistor 230, and the emitter of the unijunction transistor 224 is further coupled to the zero volt line of the power supply 220 through a capacitor 232. The base 1 of the unijunction transistor 224 is coupled through the primary winding 234a of a pulse transformer 234. The transformer is wound on a ferrite core and has a ratio of 1:1.

On end of the secondary winding 234b of the transformer 234 is coupled through the motor 212 to one side of the alternating current supply. The other end of the secondary winding 234b of the transformer 234 is coupled to the gate electrode of a thyristor or triac 236 which is connected between the motor 212 and the other side of the alternating current supply. A surge suppression circuit comprising a resistor 238 and a capacitor 240 are connected in series across the thyristor or triac 236 to protect the thyristor or triac, and reduce radio frequency interference.

35 In operation, when the temperature at the thermistor 214 is low, the thermistor resistance is high and the circuit is non-oscillatory. As the temperature increases so that the thermistor resistance decreases the transistor 216 will start to conduct at a predetermined value of the thermistor resistance set by resistor 228, and current will flow through resistor 222 to base 2 of the unijunction transistor 224. Current will also flow by way of thermistor 214 and resistor 230 to the emitter of the unijunction transistor 224 so that the transistor 224 starts to oscillate at a rate determined by the capacitor 232. The frequency of oscillation is about 1KHz. The oscillator waveform is developed across the primary winding 234a of the 1:1 transformer 234 which both shapes the pulses and provides isolation from the a.c. mains potential at the secondary winding 234b. The potential developed across the secondary winding 234b is fed to the gate of the triac 236. The triac 236 is thus fired by the oscillator pulses and, depending upon the point on the 50Hz mains cycle on which it is fired, provides a proportional amount of power to energise the motor 212. For example if the triac 236 is fired on the peaks of the a.c. waveform power will be fed to the motor 212 for two quarter cycles in each cycle and the motor will be energised effectively at half power.

40 The triac can be fired at any point of the 50Hz a.c. waveform and as a result the power fed to the motor will be varied proportionately. During normal operation, as the resistance of the thermistor varies, the firing point of transistor 224 on the a.c. waveform which appears as ripple on the +24 volt supply varies, up to a maximum allowed by the value of resistor 218. The resistor 218 can be preset to adjust the maximum power to and the speed of, the motor 212. The resistor 222 is provided to limit the current through transistor 224 in the event that the resistor 218 is set to zero ohms.

45 The transistor 216 ensures a rapid escalation of power at the commencement of oscillation, to ensure that the motor 212 does not receive power at too low a level

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which is inadequate to cause the motor to run. If that happened ver-heating and eventual failure of the motor would occur.

The resistor 230 is provided to prevent the unijunction transistor 224 from "locking on" in the event that the resistance of the thermistor 214 is reduced to a very low value.

Various modifications can, of course, be made to the invention. For example, the valve 6 could be replaced by a continuously-modulating type of valve in which the rate of flow of gas to the burner 8 is controlled according to the magnitude of the ambient temperature.

#### WHAT I CLAIM IS:-

1. A gas-fired, warm-air heating system comprising a gas flow control valve for controlling the amount of gas supplied to a burner according to the ambient temperature of a space to be heated, a heat exchanger arranged to be heated by the gas burner, a fan for directing air to be heated over the heat exchanger and for assisting the flow of warm air through a duct or ducts of the system, and means for continuously controlling the speed of the fan motor in accordance with the temperature at a position at or near the heat exchanger thereby to maintain the temperature of the air entering the space, or spaces, substantially constant.

2. A system according to Claim 1, in which the gas-flow control valve is a valve having three states, a first state in which the flow of gas to the burner is at a first, maximum rate when the ambient temperature is less than a first predetermined value, a second state in which the flow of gas is cut-off when the ambient temperature is greater than a second higher predetermined value and a third state in which the flow of gas is at a second, intermediate rate when the ambient temperature is equal to or between the said first and second predetermined values.

3. A system according to Claim 1, in which the gas-flow control valve is a continuously modulating type of valve by which the flow of gas is controlled according to the ambient temperature, the valve being arranged to supply gas to the burner at a maximum rate when the ambient temperature is less than a first predetermined value, and to reduce the rate of flow of gas as the ambient temperature increases from the first predetermined value towards a second predetermined value and to cut-off the flow of gas when the said ambient temperature is greater than the said second predetermined value of temperature.

4. A system according to Claim 1, 2 or 3, in which the gas control valve is controlled by a thermostat or like device arranged to be positioned in a suitable position in a space to be heated.

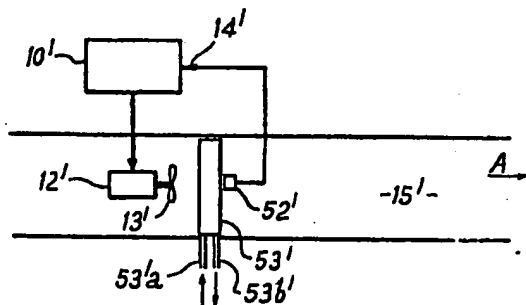
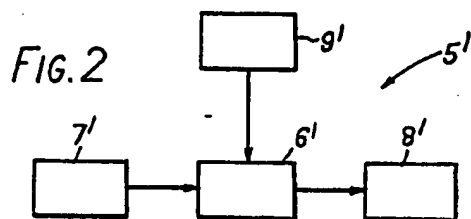
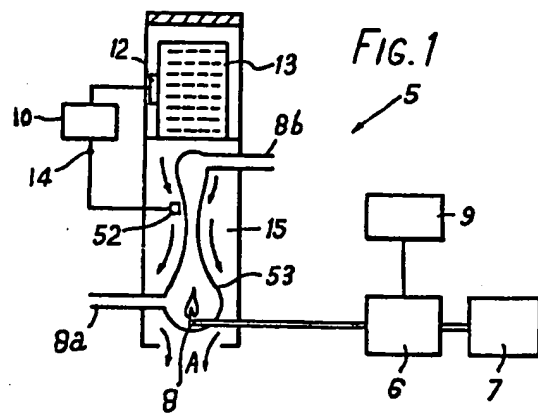
5. A system according to Claim 1, 2, 3 or 4, in which the speed of the fan is controlled by temperature-sensing means such as a thermistor.

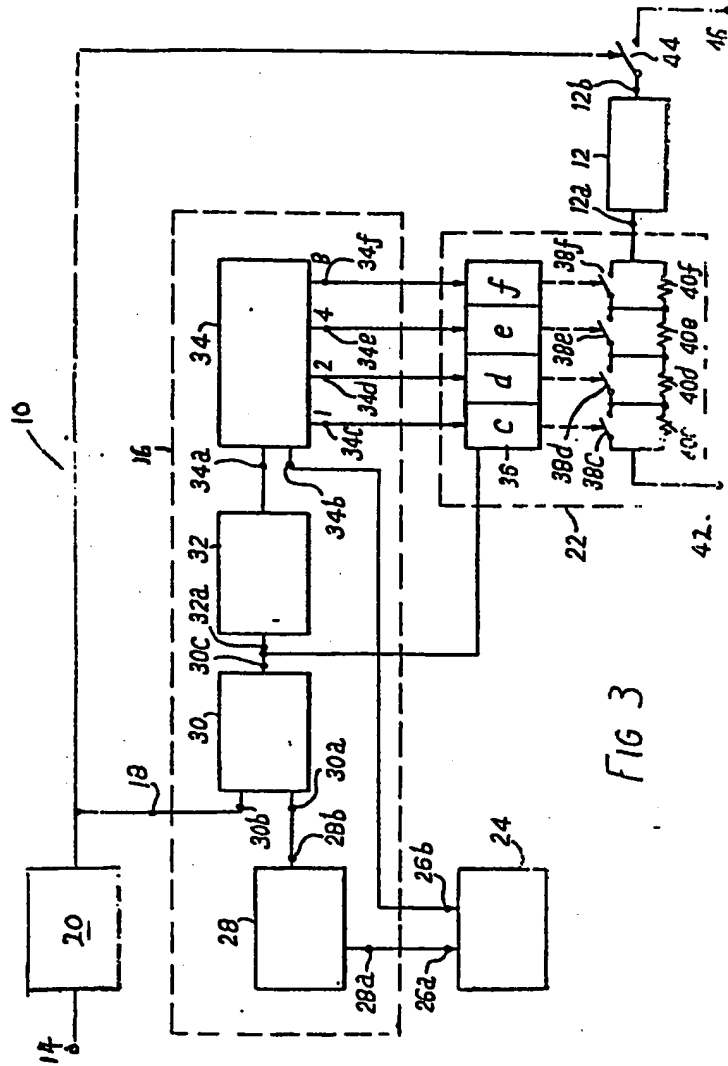
6. A system according to any one of the preceding Claims, in which the means for controlling the speed of the fan is an apparatus as described or claimed in the Complete Specification of our copending patent application No. 20200/75 (Serial No. 1552625).

7. A gas-fired, warm-air heating system substantially as hereinbefore described with reference to and as illustrated in Figure 1 or Figure 2 or Figure 1 or Figure 2 with Figure 3 or Figures 4a and b or Figure 5 of the accompanying drawings.

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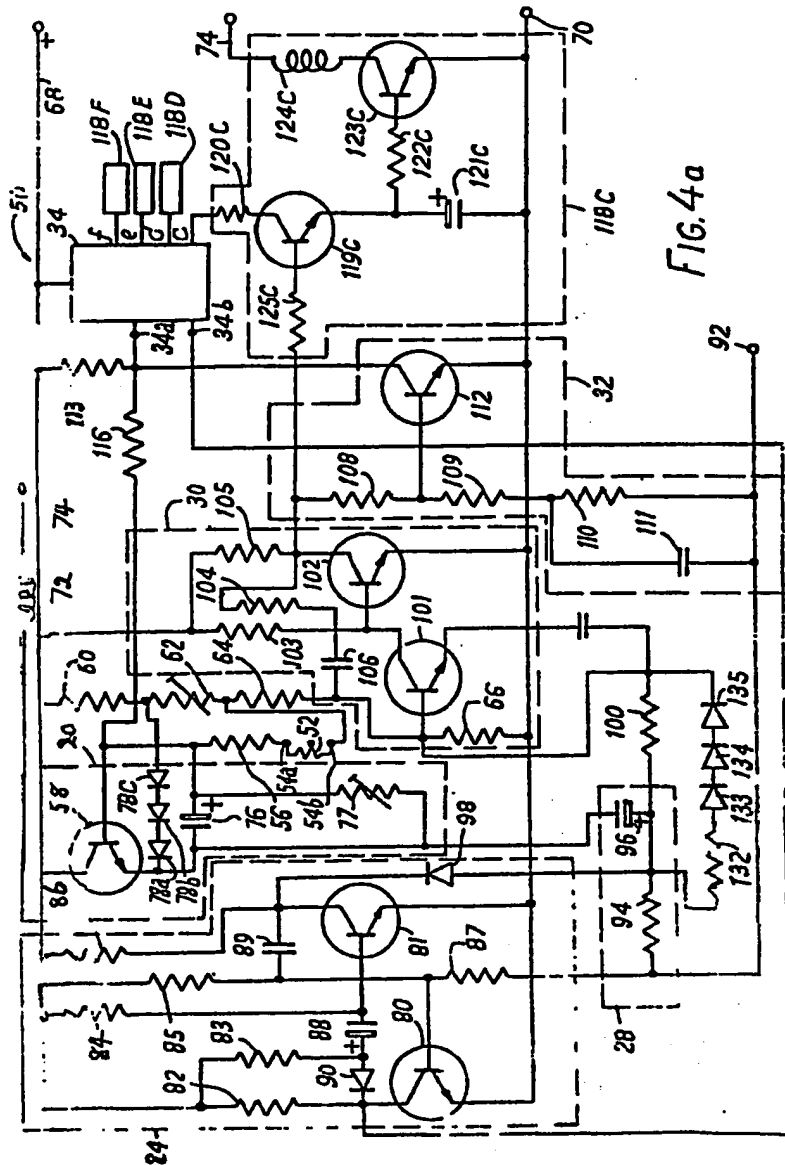


FIG. 4a

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COMPLETE SPECIFICATION

5 SHEETS

This drawing is a reproduction of  
the Original on a reduced scale

Sheet 4

